

## Supplement to original submittal to EPA for SIP change

Eli Lilly and Company  
Indianapolis, Indiana

CP 097-3341  
Plt. ID 097-00072  
Review Engineer: Dr. T.P.Sinha

= \$ 5,520

Maintenance cost

(a) Maintenance labor costs = \$4,800  $[(0.5 \text{ hr/shift}) / (8 \text{ hr/shift})] * (\text{HRS}) * (\text{\$hourly rate})$   
(b) Maintenance materials = \$4,800  $1.0 * (\text{Maintenance labor costs})$

Maintenance costs = \$(4,800 + 4,800)  
= \$ 9,600

Disposal of solvent = \$9,654 ASR \* Dsc

TOTAL DIRECT ANNUAL COSTS = (Electricity + solvent + operating + Maintenance + Disposal of solvent) Costs  
= \$24,782

INDIRECT ANNUAL COSTS

Overhead = 0.60 (Operating + Maintenance)  
= \$9,072

Property Tax = 1 percent of TCI  
= \$2,760

Insurance = 1 percent of TCI  
= \$2,760

Administrative = 2 percent of TCI  
= \$5,520

Capital Recovery = CRF \* TCI Capital recovery cost factor  
= \$276,020 \* 0.1627 is based on 10% interest rate  
= \$44,921 and 10 years of life = 0.1627

Total Indirect Costs = (Overhead + Property Tax + Insurance + Administrative + Capital Recovery)  
= \$65,034

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TOTAL ANNUAL  
COSTS

= TOTAL INDIRECT ANNUAL COSTS  
+ TOTAL DIRECT ANNUAL COSTS  
= \$(65,034 + 24,782)  
= \$ 89,816

PART II

Economic Feasibility  
for Control Technologies  
for Modules E, F, 30 Gal-A, 30 Gal-B, & C-Wing  
in Building 110

2A. Condensation Control Technology

HAP heat content:	17,000 Btu/lb
Molecular weight of HAP, Mwhap:	70.87
Emission Stream Flow, Qea:	10.0 acfm
Emission Stream Flow, Qe:	10.0 scfm
Stream Pressure, P:	1 atm
Stream Temperature, Te:	77°F
Air Pollution, HAP:	VOC
Maximum HAP conc., HAPe:	185034 ppmv
Removal efficiency, RE:	96.3%
Heat Transfer Coefficient, U:	20.0 Btu/hr- ft <sup>2</sup> -°F
System Pressure Drop, P:	5.0 inches
Temperature for 1 mm Hg vapor pressure	-54.6°F
Temperature for 100 mm Hg vapor pressure	67.9°F
Operating hours/year, HRS:	2,560 hours
Heat exchanger efficiency, HR:	95%
System pressure drop, Psys:	5.0 inches
Coolant pump motor efficiency, n:	0.65
Peak/Average Flow Ratio:	1.0 scfm/scfm
Minimum coolant velocity:	3.0 ft/sec
Coolant tube diameter:	0.375 inches
Coolant specific heat:	0.65 Btu/lb-°F
Coolant specific gravity, Sg:	7.48 lb/gal
Coolant liquid cost, US\$cool:	\$7.6/gal From vendor
Auxiliary equipment cost, AEC: (Fan, ductwork, stack, & damper)	\$25,000
Cost of Building, Bldg:	\$0.0
Cost of site preparation, SP:	\$0.0

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Electricity cost, U\$elect:	\$0.059/kwh	From Table 4.6-7, *358.6/340.1
Operating labor cost:	\$30.o/hr	From Table 4.3-6, *358.6/340.1
Maintenance labor cost:	\$30.o/hr	From Table 4.3-6, *358.6/340.1
Refrigerator efficiency, Ef:	65 percent	

Calculate Ppartial pressure of HAP in outlet stream:

$$\begin{aligned}
 P_{\text{partial}} &= 760 * (1 - 0.01RE) / (1 - RE * \\
 &\quad 1.0E-08 * HAPE) * HAPE * 1.0E-06 \\
 &= 6.33 \text{ mmHg}
 \end{aligned}$$

Condensation Curve Xint,

$$\begin{aligned}
 X_{\text{int}} &= 1 / (X_{\text{int}} + 460) \\
 &= 0.00247 \text{ (1/}^{\circ}\text{R)}
 \end{aligned}$$

Condensation curve slope,

$$\begin{aligned}
 CSI &= -(1 / (T_{\text{con}} 100\text{mm Hg} + 460)) + X_{\text{int}}/2 \\
 &= 0.00029 \text{ }^{\circ}\text{R mm Hg}
 \end{aligned}$$

$$\begin{aligned}
 \text{Calculate } T_{\text{con}} &= 1 / [(X_{\text{int}} - CSI * \text{LOG}(P_{\text{vapor}})) - 460] \\
 (-25.04 \text{ }^{\circ}\text{F}) &= -13.1 \text{ }^{\circ}\text{F}
 \end{aligned}$$

Composition of Coolant: DOWTHERM

IF  $T_{\text{con}} > 60$ , WATER  
 IF  $45 < T_{\text{con}} < 60$ , CHILLED WATER  
 IF  $-30 < T_{\text{con}} < 45$ , DOWTHERM  
 IF  $T_{\text{con}} < -30$ , FREON.

$$\begin{aligned}
 \text{Moles HAP in inlet emission stream / min,} &= Q_e / 392 * HAPE * 1.0E-06 \\
 HAPem &= 0.00472 \text{ lb-moles/min}
 \end{aligned}$$

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Moles HAP in outlet emission stream/min, HAP <sub>em</sub>	$= Q_e/392 * (1 - H_{Ape} * 1.0E-06) * P_{vapor} / (P_e - P_{vapor})$ $= 0.00017 \text{ lb-moles/min}$
Moles HAP condensed /min, HAP <sub>con</sub>	$= HAP_{em} - HAP_{om}$ $= 0.00455 \text{ lb-moles/min}$
Heat of vaporization at T <sub>con</sub> , dH	$= 709 \text{ Btu/lb-mole}$
HAP avg, spec. heat for temp T <sub>con</sub> to T <sub>e</sub> , C <sub>Phap</sub>	$= 10.84 \text{ Btu/lb-mole-}^{\circ}\text{F}$
Enthalpy change of condensed HAP	$= HAP_{con} [dH + C_{Phap} * (T_e - T_{con})]$ $= 7.66 \text{ Btu}$
Enthalpy change of air, H <sub>noncond</sub>	$= [(Q_e/392) - HAP_{em}] C_{P_{air}} (T_e - T_{con})]$ $= 13.20 \text{ Btu}$
Condenser heat load	$= 1.1 * 60 * (H_{con} + H_{noncon})$ $= 1377 \text{ Btu/hr}$
Coolant input temperature, T <sub>cool,i</sub>	$= T_{con} - 15$ $= -28.1^{\circ}\text{F}$
Coolant output temperature, T <sub>cool,o</sub>	$= T_{cool,i} + 25$ $= -3.1^{\circ}\text{F}$
Log mean temperature difference, Dt <sub>lm</sub>	$= (T_e - T_{cool,o} - 15) / \text{LN} ((T_e - T_{cool,o}) / 15)$ $= 38.9^{\circ}\text{F}$

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Area of condenser, $A_{con}$	$= H_{load} * (PkFlow/AvgFlow) / (U * DTlm)$ $= 1.77 \text{ ft}^2$
Average specific heat of coolant, $C_{pcoolant}$	$= 0.65 \text{ Btu/lb } ^\circ\text{F}$
Coolant flow rate, $Q_{cool}$	$= MAX(H_{load} / (C_{pcoolant} (T_{cool0} - T_{cool1}), F_{min} * \\ * T_d^2 * D_{ens} * 7.48 \text{ gal/ft}^3 * 3 * 3600 \text{ sec/hr})$ $= 590 \text{ lb/hr}$
Total coolant required, $Q_{Ctot}$	$= 200 \text{ gallons}$ (Estimated)
Refrigeration capacity, Ref	$= H_{load} * (PkFlow/AvgFlow) / 12000$ $= 0.11 \text{ tons}$
Recovered product, $Q_{rec}$	$= 60 * HAP^{con} * M_{whap}$ $= 19.33 \text{ lb/hr}$

CAPITAL COSTSDIRECT COSTSPurchased equipment costs

Refrigeration Capital Cost, RCC	$= \$28,919$	From Table 4.8-4, corrected to April, 1992 dollars
Condenser Capital Cost, CCC	$= \$5,836$	From Figure 4.8-3, corrected to April, 1992 dollars
Auxiliary Equipment Cost, AEC	$= \$25,000$	Parameter
Cost of Cooling	$= Q_{Ctot} * U\$cool$	

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Liquid, T\$cool	= \$1,520
Total Equipment Cost, A	= \$ ( RCC + CCC + AEC + T\$cool ) = \$61,275
Instrumentation Cost, I	= 0.10 * A = \$6,128
Sales Taxes, S	= 0.05 A = \$3,064
Freight, F	= 0.05 * A = \$3,064
Purchased Equipment Costs, B	= \$ (A + I + S + F) = \$ 73,530

Direct Installation Costs

Foundation and Supports	= 0.08B = \$5,882
Handling and Erection	= 0.14B = \$10,294
Electrical	= 0.08B = \$5,882
Piping	= 0.02B = \$1,471
Insulation for ductwork	= 0.10B = \$7,353
Painting	= 0.01B = \$735

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Direct  
Installation  
Costs, C = (Foundation and Supports + Handling and  
Erection + Electrical + Piping +  
Insulation + Painting)  
= \$31,617

Site Preparation,  
D = \$0

Building Cost,  
E = \$0

TOTAL DIRECT  
COSTS = \$(B + C + D + E)  
= \$105,147

INDIRECT COSTS (INSTALLATION)

Engineering = 0.10 B  
= \$7,353

Construction = 0.05 B  
and field expense = \$3,677

Contractor Fees = 0.10 B  
= \$7,353

Start-Up = 0.02 B  
= \$1,470

Performance Test = 0.01 B  
= \$735

Contingencies = 0.03 B  
= \$2,205

TOTAL INDIRECT  
COSTS = (Engineering + Construction + Contractor Fees  
+ Start-Up + Performance Test +  
Contingencies) costs  
= \$ 22,793

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TOTAL CAPITAL INVESTMENT (TCI) = (TOTAL DIRECT COSTS  
+ TOTAL INDIRECT COSTS)  
= \$(105,147 + 22,793)  
= \$ 127,940

## DIRECT ANNUAL COSTS

System Pressure Drop, $P_{sys}$	= 5 inches	Parameter
Fan power requirement, $F_p$	= 23 kwh/yr	$1.81E-04 * Q_{ea} * P * HRS$
Refrigeration power requirement, $R_p$	= 1588.9 kwh/yr	$H_{load} * HRS * 2.9E-04$ kwh/btu/Er
Coolant pumping requirement, $P_p$	= 245.3 kwh/y	$[2.52 E-04 * Q_{cool}/60/Sg$ $* H * Sg/7.48/n] * HRS$ $* 0.748$ From Table 4.6-8 of HAP manual
Annual electricity cost	= \$110	$U_{selec} * (F_p + R_p + P_p)$
Cost of Refrigerant	= \$0	
<u>Operating costs</u>		
(a) Operating labor costs	= \$4,800	$[(0.5 \text{ hr/shift}) / (8 \text{ hr/shift})]$ $* (HRS) * (\$ \text{hourly rate})$
(b) Supervisory Costs	= \$720	$0.15 * (\text{Operating labor costs})$
Operating costs	= \$(4,800 + 720) = \$ 5,520	

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Maintenance cost

(a) Maintenance labor costs	= \$4,800	$[(0.5 \text{ hr/shift}) / (8 \text{ hr/shift})] \times (\text{HRS}) \times (\text{\$hourly rate})$
(b) Maintenance materials	= \$4,800	$1.0 \times (\text{Maintenance labor costs})$
Maintenance costs	= \$(4,800 + 4,800)	
	= \$ 9,600	
Disposal of recovered HAP	= \$208	$V_{\text{hap}} \times \text{ER} \times 2000 \times \text{RE}$
TOTAL DIRECT ANNUAL COSTS	= (Electricity + Refrigerant + Operating + Maintenance + Disposal of recovered HAP) Costs	
	= \$15,438	

INDIRECT ANNUAL COSTS

Overhead	= 0.60 * (Operating + Maintenance)	
	= \$9,072	
Property Tax	= 1 percent of TCI	
	= \$1,279	
Insurance	= 1 percent of TCI	
	= \$1,279	
Administrative	= 1 percent of TCI	
	= \$1,279	
Capital Recovery	= CRF * TCI	Capital recovery cost factor of life = 0.1627 is based on 10% interest rate and 10 years
	= \$0.1627 * 127,940 .	
	= \$20,822	
Total Indirect costs	= (Overhead + Property Tax + Insurance + Administrative + Capital Recovery) Costs	
	= \$33,731	

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TOTAL ANNUAL COSTS	= TOTAL INDIRECT ANNUAL COSTS
	+ TOTAL DIRECT ANNUAL COSTS
	= \$(33,731 + 15,438)
	= \$ 49,169

2.B Absorption Control Technology

Average flow rate, $Q_{avg}$	= 10 scfm	
Maximum flow rate, $Q_e$	= 10 scfm	
Temperature, $T_e$	= 77 °F	
HAP	= VOC	
HAP concentration, $HA_{Pe}$	= 185034 ppmv	
Pressure, $P_e$	= 760 mm Hg	
Removal efficiency, RE	= 58.8%	
Mol.wt. of emission stream, $M_{we}$	= 70.87 lb/lb-mol	
Solvent used	= Water	
Slope of equilibrium curve, $m$	= 2.64	from Perry's Handbook Figure 14-14
Mol. Wt. of solvent, $M_{w_{sol}}$	= 18 lb/lb-mol	
Disposal cost of solvent, $D_{sc}$	= \$266/1,000 gals	
Schmidt # in gas, $Sc_g$	= 1.24	

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Schmidt # in liquid,	$S_{cl}$	= 804	$U_1/(P_1 \cdot D_1)$
Solvent density,	$D_1$	= 62.18 lb/ft <sup>3</sup>	
Solvent Viscosity,	$U_1$	= 0.815 cp	Weast Pg. F-42
Absorption factor,	AF	= 1.6	from HAP manual example case
Packing constant,	A	= 28	
Packing constant,	e	= 0.74	
Fraction of Flooding $V_{,f}$		= 0.6	
Packing constant,	b	= 3.82	
Packing constant,	c	= 0.41	
Packing constant,	d	= 0.45	
Packing constant,	Y	= 0.0125	
Packing constant,	s	= 0.22	
Packing constant,	g	= 11.13	
Packing constant,	r	= 0.00295	

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Bed type = Single

Packing material  
cost,  $P_{cost}$  = \$12.75/ft<sup>3</sup>

Hours/yr = 2560

Electrical cost = \$0.059/kwh

Water cost = \$0.20/1,000 gals

Operating labor  
cost = \$30/hr

Maintenance labor  
cost = \$30/hr

CALCULATIONS

Gas stream  
flow rate,  $G_{mol}$  = 1.55 lb-mol/hr  $0.155 * Q_e$

Liquid flow  
rate,  $L_{mol}$  = 6.55 lb-mol/hr  $AF * m * G_{mol}$

Liquid flow  
rate,  $L_{gal}$  = 0.24 gal/min  $[L_{mol} * M_{wsol} * (1/D_l) * 7.48] / 60$

Solvent flow  
rate,  $L$  = 118 lb/hr  $M_{wsol} * L_{mol}$

Gas stream  
flow rate,  $G$  = 109.85 lb/hr  $M_{we} * G_{mol}$

Density of  
gas,  $D_g$  = 0.181 lb/ft<sup>3</sup>  $P * M / (R * T)$

Abscissa,  $ABS$  = 0.058  $L / G * (D_g / D_l)^2$

Ordinate,  $ORD$  = 0.14 Read from Figure 4.7-2

Gas flow at  
flooding,  $G_{af}$  = 0.874 lb/hr  $[ORD * D_g * D_l * G_c / ((a/e^3) * (U_l^{0.2}))]^{0.5}$

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Gas flow,	Ga	= 0.524 lb/hr	$f * Gaf$
Area of column,	Acol	= 0.06 ft <sup>2</sup>	$G/(3,600 * Ga)$
Diameter of column		= 1.00 ft	$1.13 * Acol^{0.5}$
# Gas transfer units,	Nog	= 2	Equation 4.7-13, HAP Manual
Liquid flow rate,	L"	= 2025 lb/hr-ft <sup>2</sup>	$L/Acol$
Ht of gas transfer unit,	Hg	= 3.048 ft	$[b * (3600 * Ga)^c / (L''^d) * Scg]$
Ht of Liq transfer unit,	Hl	= 1.63 ft	$Y * (L''/U1'')^s * Sc1^{0.5}$
Ht of transfer unit,	Hog	= 4.07 ft	$Hg + (1/AF) * Hl$
Column Height,	Htcol	= 8.1 ft	$Nog * Hog$
Total column height,	Httot	= 10.4 ft	$HTcol + 2 + 0.25 * Dcol$
Volume of packing material,	Vpack	= 6.4 ft <sup>3</sup>	
Pressure drop through column,	Pa	= 2.74 lb/ft <sup>2</sup> -ft	
Total pressure drop,	Ptot	= 4.28 in H <sub>2</sub> O	$Pa * HTcol/5.2$

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## CAPITAL COSTS

DIRECT COSTSPurchased equipment costs

Absorber Tower  
Capital Cost, RCC = \$4,967 From Figure 4.7-4, corrected  
to April, 1992 dollars

Auxiliary Equipment  
Cost, AEC = \$25,000 Parameter

Packing material,  
PM = \$86 Vpack \* Pcost, corrected to  
April, 1992 dollars

Total Equipment  
Cost, A = \$ ( RCC + AEC + PM)  
= \$30,053

Instrumentation,  
I = 0.10 \* A  
= \$3,005

Sales Taxes, S = 0.05 A  
= \$1,503

Freight, F = 0.05 \* A  
= \$1,503

Purchased  
Equipment  
Costs, B = \$ (A + I + S + F)  
= \$ 36,064

Direct Installation Costs

Foundation and  
Supports = 0.012 B  
= \$4,328

Handling and  
Erection = 0.4 B  
= \$14,425

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Electrical	= 0.01 B
	= \$361
Piping	= 0.03 B
	= \$10,819
Insulation for ductwork	= 0.01 B
	= \$361
Painting	= 0.01B
	= \$361
Direct Installation Costs, C	= (Foundation and Supports + Handling and Erection + Electrical + Piping + Insulation + Painting) Costs
	= \$30,654
Site Preparation, D	= \$0
Building Cost, E	= \$0
TOTAL DIRECT COSTS	= \$(B + C + D + E)
	= \$66,718

INDIRECT COSTS (INSTALLATION)

Engineering	= 0.10 B
	= \$3,606
Construction and field expense	= 0.10 B
	= \$3,606
Contractor Fees	= 0.10 B
	= \$3,606
Start-Up	= 0.01 B
	= \$361
Performance Test	= 0.01 B
	= \$361

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Contingencies = 0.03 B  
= \$1,082

TOTAL INDIRECT COSTS = (Engineering + Construction + Contractor Fees + Start-Up + Performance Test + Contingencies) costs  
= \$ 12,622

TOTAL CAPITAL INVESTMENT (TCI) = (TOTAL DIRECT COSTS + TOTAL INDIRECT COSTS)  
= \$(66,718 + 12,622)  
= \$ 79,340

DIRECT ANNUAL COSTS

Actual em. str. flow rate,  $Q_{ea}$  = 10 acfm

Annual electricity requirement,  $F_p$  = 20 kwh/yr

Annual electricity cost,  $R_p$  = \$1  $F_p * U\$Elec$

Annual solvent requirement,  $Asr$  = 36,293 gallons

Annual solvent cost,  $ASC$  = \$7  $ASR * P_{cw} * 1/1000$

Operating costs

(a) Operating labor costs = \$4,800  $[(0.5 \text{ hr/shift}) / (8 \text{ hr/shift})] * (HRS) * (\$ \text{hourly rate})$

(b) Supervisory Costs = \$720  $0.15 * (\text{Operating labor costs})$

Operating costs = \$(4,800 + 720)  
= \$ 5,520

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(b) Maintenance materials = \$4,800  $1.0 * (\text{Maintenance labor costs})$

Maintenance costs = \$(4,800 + 4,800)  
= \$ 9,600

Disposal of solvent = \$9,654 ASR \* Dsc

TOTAL DIRECT ANNUAL COSTS = (Electricity + solvent + operating + Maintenance + Disposal of solvent) Costs  
= \$24,782

INDIRECT ANNUAL COSTS

Overhead = 0.60 \* (Operating + Maintenance)  
= \$9,072

Property Tax = 1 percent of TCI  
= \$793

Insurance = 1 percent of TCI  
= \$793

Administrative = 2 percent of TCI  
= \$1,587

Capital Recovery = CRF \* TCI Capital recovery cost factor  
= \$79,340 \* 0.1627 is based on 10% interest rate  
= \$12,912 and 10 years of life = 0.1627

Total Indirect costs = (Overhead + Property Tax + Insurance + Administrative + Capital Recovery) Costs  
= \$25,158

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TOTAL ANNUAL  
COSTS

= TOTAL INDIRECT ANNUAL COSTS  
+ TOTAL DIRECT ANNUAL COSTS  
= \$(25,158 + 24,782)  
= \$ 49,940

Summary of Economic Feasibility Analysis1. CONDENSER

MODULE	TOTAL VOC EMISSIONS  (TONS/YR)	RACT CTG CAPITAL COST	RACT CTG ANNUAL COST	ANNUAL COST/TON VOC CONTROLLED	ANNUAL INCREMENTAL COST/TON VOC CONTROLLED
A' Uncont. Prop. RACT CTG RACT *Increm.Red	4.04 2.71 1.85 0.86	\$283,498	\$81,909	\$37,401	\$95,243
B Uncont. Prop. RACT CTG RACT *Increm.Red	2.83 2.07 1.44 0.63	\$283,498	\$81,909	\$58,927	\$130,014
C Uncont. Prop. RACT CTG RACT *Increm.Red	3.43 2.31 1.57 0.74	\$283,498	\$81,909	\$44,037	\$110,688
D Uncont. Prop. RACT CTG RACT *Increm.Red	5.65 3.20 2.08 1.12	\$283,498	\$81,909	\$22,944	\$73,133

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E					
Uncont.	5.24				
Prop.RACT	3.04				
CTG RACT	1.99	\$127,940	\$49,169	\$39,366	
*Increm.Red	1.05				\$46,828
F					
Uncont.	5.24				
Prop.RACT	3.04				
CTG RACT	1.99	\$127,940	\$49,169	\$39,366	
*Increm.Red	1.05				\$46,828
30 Gal-A					
Uncont.	0.49				
Prop.RACT	0.42				
CTG RACT	0.22	\$127,940	\$49,169	\$182,107	
*Increm.Red	0.20				\$245,845
30 Gal-B					
Uncont.	0.45				
Prop.RACT	0.38				
CTG RACT	0.19	\$127,940	\$49,169	\$189,112	
*Increm.Red	0.19				\$258,784
C-Wing					
Uncont.	1.94				
Prop.RACT	1.42				
CTG RACT	0.88	\$127,940	\$49,169	\$46,386	
*Increm.Red	0.54				\$91,053
TOTAL					
Uncont.	29.3				
Prop.RACT	18.6				
CTG RACT	12.2	\$1,773,692	\$573,481	\$33,537	
*Increm.Red	6.38				\$89,887

## Supplement to original submittal to EPA for SIP change

Eli Lilly and Company  
Indianapolis, Indiana

CP 097-3341

Plt. ID 097-00072

Review Engineer: Dr. T.P.Sinha

2. Absorber

MODULE	TOTAL VOC EMISSIONS  (TONS/YR)	RACT CTG CAPITAL COST	RACT CTG ANNUAL COST	ANNUAL COST/TON VOC CONTROLLED	ANNUAL INCREMENTAL COST/TON VOC CONTROLLED
A Uncont. Prop.RACT Aft. Absrb. *Increm.Red	4.04 2.71 2.26 0.45	\$276,020	\$89,816	\$50,458	\$199,591
B Uncont. Prop.RACT Aft. Absrb. *Increm.Red	2.83 2.07 1.77 0.30	\$276,020	\$89,816	\$86,362	\$299,387
C Uncont. Prop.RACT Aft. Absrb. *Increm.Red	3.43 2.31 2.01 0.30	\$276,020	\$89,816	\$63,251	\$299,387
D Uncont. Prop.RACT Aft. Absrb. *Increm.Red	5.65 3.20 2.93 0.27	\$276,020	\$89,816	\$33,021	\$332,652
E Uncont. Prop.RACT Aft. Absrb. *Increm.Red	5.24 3.04 2.76 0.28	\$79,340	\$49,940	\$20,137	\$178,357